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Ultrasonic Investigation on the Effect of Corrosion Inhibitor in Mild Steel

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ABSTRACT

Corrosion behavior of mild steel samples of thickness around 3.5 mm in 1M HCl solution in the room temperature was determined. The inhibition studies were made on the sample by two inhibitors namely (i) Fly ash and (ii) Silica fume. The inhibitors were added to the acid solution in various concentrations like 0.1%, 0.2%. Precise ultrasonic velocity measurements were performed by through transmission method by generating probes of 2 MHz is used in the mild steel samples of as received, corroded and in the presence of inhibitor added sample. It was found that there is an increase in longitudinal ultrasonic velocity in the inhibitor added samples as compared to the other as received and corroded samples. Further, the inhibitors are moderately inhibiting the corrosion and there may be a decrease in the attack of corrosion reaction from the acid solution to the mild steel samples. This will increase the velocity in the inhibitor used sample. There was a decrease in ultrasonic velocity in the corroded sample indicates there is a microstructural variation taking place due to corrosion The velocity was found to be highest in the silica fume inhibitor used steel sample acquiring a value of 5812 m/s and lowest in the corroded steel sample acquiring a value of 4908 m/s. The studies clearly indicate the immense possibility of the application of ultrasonic NDT techniques in assessing the corrosion damages and the inhibition mechanism for the adsorption on the mild steel surface to estimate the level of degradation and the application of inhibitors to enhancing the life of steel components.

Keywords: Mild steel, Corrosion, Inhibitors, through transmission, ultrasonic.

INTRODUCTION

Mild steel is widely used as an inexpensive structural metal for fabrication of large number of products. Corrosion of metals generally occurs in the presence of oxygen and moisture and involves two electrochemical reactions. Oxidation occurs

at anodic site and reduction occurs at cathodic site. In acidic medium hydrogen evolution reaction predominates. Corrosion inhibitors reduce or prevent these reactions, they are adsorbed onto the metal surface and act by forming barrier to oxygen and moisture and some of the inhibitors facilitate formation of passive film on the metal surface. Most of the well-known acid inhibitors used in industry are organic compounds having multiple bonds in their molecules that mainly contain nitrogen, sulphur, oxygen atoms through which they get adsorbed on the metal surface [1-3].

Ultrasonic inspection of metallic materials is an adequate technique that could help to reduce and prevent catastrophic failures in pipelines systems and industrial equipments. Conventional techniques have not exhibited good detectability for corrosion damage inside the steels, but very good results have been obtained using non-conventional methods like attenuation, backscattering signal, spectral analysis and ultrasonic velocity change [4].

Ultrasonic through transmission measurements are used for a quality control of products in various areas of industry. This technique is sufficiently fast to enable monitoring deviations of thickness or ultrasound velocity under industrial conditions. The estimation of appropriate thickness or ultrasound velocity values is based on measurement of the time of flight of an ultrasonic signal in the test sample. In this case propagation time and distortion of the received signal waveform includes information about measurement object and its internal structure. The delay time estimation is one of the most essential procedures in ultrasonic through transmission measurements. The time interval between these two signals is the physical quantity necessary to measure [5].

The objective of this study was to investigate the ultrasonic velocity changes in corrosion inhibitive action of the inhibitor species namely fly ash and silica fume on the mild steel surface in 1M of HCl solution in the room temperature was determined. Precise ultrasonic velocity measurements were performed by through transmission method by generating probes of 2 MHz is used in the mild steel samples of as received, corroded and in the presence of inhibitor species added samples. The inhibition efficiency (IE) and the ultrasonic velocity changes with respect to the action of the inhibitors were evaluated. The change in velocity in the absence and presence of inhibitors leads to some conclusions concerning the mechanism for the adsorption and the inhibiting action on the mild steel surface in the acid solution. The inhibition efficiency were measured by weight-loss method.

EXPERIMENTAL

The Hydrochloric acid HCl solution was prepared by mixing 26ml of Hydrochloric acid (AR) in 1000mlof distilled water. Inhibitors of Fly ash and Silica fume concentration of 0.1% and 0.2% was prepared in distilled water.

Mild steel specimens of thickness around 3.5mm were cut to an overall size of 50mm x 10mm. The specimens were polished emery papers of 150, 320 and 600 grades, degreased with trichloroethylene, washed in distilled water and finally dried. The chemical composition of this steel in given in Table 1.

The ultrasonic velocity were taken on the mild steel samples using Digital Ultrasonic Pulse Echo Velocity Meter (Liquid/Solid), VI Microsystems with 2MHz transducer with the olive oil as the couplant with the accuracy of 0.05μs. The block diagram is shown in Fig. 1.

RESULT AND DISCUSSION

Ultrasonic Velocity

The damage caused by corrosion changes the way in which ultrasonic waves are propagated. The presence of dissolved hydrogen in the acid solution may attack into the metal. It will affect the elasticity modulus reducing the longitudinal and shear ultrasonic waves. It is noticed that the ultrasonic velocity decreases in the corroded sample due to that acid solution increases the steel susceptibility to corrosion damages. When inhibitors were injected into solution, there were clear indications that a reduction in corrosion rate was achieved. Apparently, adsorbed molecules of the inhibitor compound decrease the active surface area where both electrochemical reactions take place, delaying the corrosion of the steel. It acts as a favorable path for the transmission of sound there by the velocity increases. As a result, more damage such as blistering and cracking would be expected in the samples tested in the inhibitor presence was reduced. The increase in velocity of silica fume inhibitors of concentration 0.2% indicates that the molecular interactions in the adsorbed layer will be more attractive towards the mild steel. It may be attributed to the fact that chloride ions being less hydrated and are strongly adsorbed on the mild steel surface by creating excess negative charge towards the solution phase, which favors the adsorption on the surface[6]. This will facilitates the inhibitor absorption on the mild steel surface is more and leads to the increase in velocity and the inhibition efficiency, as listed in Table.2. and Table.3 & 4.

Kruger parameters[7] previously demonstrated that the backwall echoes spectrum changes with hydrogen attack is due to the presence of extra of scatterer's. Higher attenuation levels are observed in attacked samples because corrosion damage can be considered itself as an additional scatterer. This is especially certain at high ultrasonic frequencies. Ultrasonic analysis of the samples showed that the velocity decreases in the corroded sample when the quantity of extra scatterer's is more in the sample due to corrosion.

A theoretical study[8] showed that microcracks in a material affect the bulk modulus of elasticity and, thus, reduce the velocity in longitudinal and shear waves. They also predicted the decrease in the velocity of the longitudinal waves will be more than that of shear waves. This will agree with the value of our measurements.

Weight loss measurements

The mild steel strips of approximate size of 50mm x 10mm x 3.5mm were used for weight loss measurements. Weight loss measurements were carried out at room temperature for 24 h in 1M HCl solutions.

The value of corrosion rate (ρ_{corr}) was calculated from the following equation

$$\rho_{corr}\ (g.cm^{-2}.min^{-1}) = \frac{m_1 - m_2}{At}$$

Where m_1 and m_2 are the masses of the specimen before and after corrosion. A is the total area of the specimen and t is the corrosion time. With the calculated corrosion rate, inhibition efficiency (IE) was calculated using the following equation.

$$IE = \frac{\rho^0_{corr} - \rho_{corr}}{\rho^0_{corr}} \times 100$$

Where ρ^0_{corr} and ρ_{corr} are the corrosion rate in absence and presence of the inhibitors respectively.

Table 1. Chemical composition of Mild Steel

	Concentration (wt %)								
Mild steel	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
	0.14	0.03	0.32	0.05	0.2	0.01	0.01	0.01	Balance

Table 2. Ultrasonic Velocity for the Mild Steel Samples.

Sample	Thickness (mm)	Longitudinal Velocity (ms^{-1})	Shear Velocity (ms^{-1})
As received	3.55	5939	2934
Corroded	3.26	4908	2422
Silica Fume 0.1%	3.25	5563	2725
Silica Fume 0.2%	3.25	5812	2812
Fly ash 0.1%	3.32	5486	2697
Fly ash 0.2%	3.32	5726	2792

Table 3. Inhibition efficiency of mild steel in 1N HCl with Silica fume.

Sample	Initial Weight (gm)	Final Weight (gm)	Inhibition Efficiency (%)
As received	31.801	30.787	--------
Silica Fume 0.1%	28.072	27.242	18
Silica Fume 0.2%	29.213	28.822	61

Table 4. Inhibition efficiency of mild steel in 1N HCl with Fly ash.

Sample	Initial Weight (gm)	Final Weight (gm)	Inhibition Efficiency (%)
As received	27.607	26.318	--------
Fly Ash 0.1%	25.700	24.712	23
Fly Ash 0.2%	26.278	25.621	40

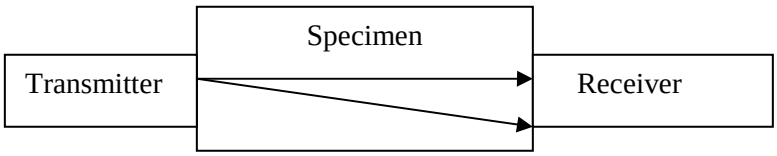

Figure 1. Through Transmission Method.

CONCLUSIONS

The non destructive techniques using ultrasonic velocity are applied on the samples to investigate the effect of corrosion inhibitors preventing the damage loss due to corrosion. Ultrasonic longitudinal velocity was found to be decrease by almost 17% in the corroded sample as compared to the as received. Therefore the ultrasonic technique is a more sensitive to monitor the inhibitive action of the inhibitors in corrosion. The Inhibitors which work well in preventing general corrosion is demonstrated. To reliably determine the internal conditions of the material, the non destructive approach is essential. From the results of velocity and inhibition efficiency the Silica fume inhibitor of 0.2% concentration shows good inhibition property.

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